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Description

Device for controlling the drawing process in a transfer press

The invention relates to a device for controlling the drawing process in a transfer press according to the preamble of claim 1.

In a press in the form of a transfer press, a workpiece to be deformed is held between two tool parts acting in opposition to one another. One of the two tool parts, which is formed particularly as a negative mold, is movable between an upper and a lower reversal point by a mechanical crank mechanism driven at a constant rotational speed. In this case, the movement from the upper to the lower reversal point is designated as a prestroke, and the subsequent movement from the lower to the upper reversal point is designated as the return stroke. The movement of the tool part driven by the crank mechanism is predetermined by the design of the crank mechanism and by its rotational speed. During one work cycle of the drawing process, said work cycle comprising prestroke and return stroke, the crank mechanism executes one complete revolution. Since the rotational speed of the crank mechanism is constant, there is a fixed relation between the crank angle and the time. It is thus possible, instead of the respective crank angles, to consider time points corresponding to these. The following

description also makes use of this relation. The other tool part, which is formed particularly as a drawing cushion, is connected via a piston rod to the piston of a hydraulic differential cylinder. The movement of the piston rod is controlled by the supply of pressure medium into a first chamber of the differential cylinder and by the discharge of pressure medium out of the other chamber in each case. The movement of the tool part held on the piston rod can be influenced, independently of the movement of the crank mechanism, by controlling the flow of pressure medium to and from the differential cylinder. A work cycle of the drawing process of the press is divided into a series of successive time segments. During a first time segment, which extends within the prestroke in the selected example, the rod-side face of the piston is acted upon by pressure medium in such a way that the differential cylinder accelerates a second tool part to an extent such that, when the first tool part impinges on the second tool part, both tool parts move virtually at the same speed. In a second time segment, which follows the first time segment within the prestroke and which extends as far as the lower reversal point, the two tool parts bear from mutually opposite sides against the workpiece and deform the latter. During deformation, the two tool parts approach one another even further. At the lower reversal point, a decompression of the pressure medium in the differential cylinder takes place. With the reversal in

direction of movement of the crank mechanism, the return stroke commences with a further time segment which extends at most until the upper reversal point is reached. In this time segment, the second tool part can either move into a particular extraction position or first move, together with the crank mechanism, in the direction of the upper reversal point. In both instances, the speed of the second tool part driven by the differential cylinder is no higher than the speed of the tool part driven by the crank mechanism. The pump provided for supplying the differential cylinder with pressure medium must be designed such that it is capable of accelerating the second tool part during the first time segment, as described above. This time segment is the time segment with the highest pressure medium requirement during a work cycle. Since the pump has to be designed for the highest pressure medium requirement, it is overdimensioned for time segments with a lower pressure medium requirement and consumes more energy than is necessary in these time segments. Such devices for controlling the drawing process in a transfer press have been offered and sold by Mannesmann Rexroth AG (now trading as Bosch Rexroth AG).

The object on which the invention is based is to improve the device initially mentioned for controlling the drawing process, with the aim of reducing the energy requirement.

This object is achieved by means of the features specified in claim 1. The invention makes use of the consideration that a high pressure is required only during the first time segment of the drawing process, and that, in at least one further time segment of a work cycle, a pressure lower than this pressure is sufficient for the movement of the second tool part. Although the use of a low-pressure pump, necessary for this purpose, increases the initial costs of the press, these extra costs are more than compensated, however, by savings in operating costs, and therefore, over the entire useful life of the press, the energy saving is predominant.

Advantageous developments of the invention are characterized in the subclaims. They relate to measures which lead to a further energy saving, and to details of devices of this type. By virtue of these measures, inter alia, a cylinder having a smaller construction size may be used. Moreover, the cooling capacity required decreases. A tank having smaller dimensions may be used for the pressure medium.

The invention is explained in more detail below, together with its further particulars, by means of three exemplary embodiments illustrated in the drawings in which:

figure 1 shows a diagrammatic illustration of a first device, formed according to the invention, for controlling the drawing process in a transfer

press,

figure 2 shows a graph, in which the movement of the two tool parts of the transfer press illustrated in figure 1 during the individual time segments of a work cycle is illustrated,

figure 3 shows the hydraulic part of a second device, formed according to the invention, for controlling the drawing process in a transfer press,

figure 4 shows the hydraulic part of a third device, formed according to the invention, for controlling the drawing process in a transfer press,

figure 5 shows an enlarged illustration of a cylinder used in figure 4,

figure 6 shows the rod-side annular face, acted upon by pressure medium, of the cylinder illustrated in figure 5, and

figure 7 shows the bottom-side faces, acted upon by pressure medium, of the cylinder illustrated in figure 5.

Figure 1 shows a diagrammatic illustration of a transfer press and of a first device for controlling the drawing process according to the invention. A workpiece 10 to be deformed is held between two tool parts 11 and 12 which act in opposition to one another and of which the tool part 11 is formed as a negative mold and the tool part 12 has a drawing cushion. A mechanical crank mechanism 13 driven at a constant rotational speed by a motor, not illustrated in

figure 1, moves the tool part 11 between an upper reversal point OT and a lower reversal point UT, the lower limit of the tool part 11 being designated as reference position s_s. A hydraulic differential cylinder 15 with a piston 16 and with a piston rod 17 engaging on the tool part 12 moves the tool part 12 within the range delimited by the reversal points OT and UT. The upper limit of the tool part 12 is in this case designated as reference position s_k. A rotary-angle transducer 20 converts the angular position φ on the crank mechanism 13, said angular position being a measure of the position s_s of the tool part 11, into an electrical voltage signal u_φ. A displacement transducer 21, illustrated symbolically by a ruler, converts the position s_k of the tool part 12 into a further voltage signal u_{sk}. The voltage signals u_φ and u_{sk} are fed as input signals to a computing circuit 22. The computing circuit 22 links the input signals, according to predetermined algorithms, to form control signals u_{stb} and u_{sts} which control the supply of pressure medium to the chambers of the differential cylinder 15, said chambers being given the reference symbols 15s and 15b.

A first pump 25, formed as a fixed-displacement pump, conveys pressure medium out of a tank 26 and charges a pressure accumulator 27 to a pressure p_{sH}, the magnitude of which is limited by a pressure cutoff valve 28. A further pump 30, likewise formed as a fixed-displacement pump, conveys pressure medium out of the tank 26 and charges a

further pressure accumulator 31 to a pressure p_{sN}, the magnitude of which is limited by a further pressure cutoff valve 32. The pressure p_{sH} is selected such that the tool part 12 can be moved at the maximum acceleration required during operation. The pressure p_{sN} is markedly lower than the pressure p_{sH}. In an exemplary embodiment, p_{sN} is of the order of one quarter of p_{sH}.

A proportional valve 35 and a switching valve 36 controls the supply of pressure medium from the pressure accumulators 27 and 31 to the chambers 15s and 15b of the differential cylinder 15 according to the control signals u_{stb} and u_{sts} transmitted by the computing circuit 22. A pressure accumulator 31 is connected to the rod-side chamber 15s of the differential cylinder 15 via a nonreturn valve 39 and via hydraulic lines 40 and 41. In the position of rest of the valve 35, as illustrated in figure 1, this being one of the two end positions of this valve, the chamber 15b is connected to the tank 26 via a further hydraulic line 42. The connection between the nonreturn valve 39 and the chamber 15b is shut off in the position of rest of the valve 35. When the valve 36, too, is in the position of rest illustrated in figure 5, the connection between the pressure accumulator 27 and the line 41 is shut off, and the chamber 15s is acted upon only by the pressure p_{sN} of the pressure accumulator 31. In the other end position of the valve 35, which corresponds to the maximum value of the control signal u_{stb}, the chamber

15b is also acted upon by the pressure p_{sN} in addition to the chamber 15s. In the case of values of the control signal u_{stb} which lie between zero and its maximum value, the chamber 15b is connected both to the tank 26 and to the line 40, the size of the respective passage cross sections being determined by the respective magnitude of the control signal u_{stb}.

When the valve 36 is in the working position, the chamber 15s is acted upon by the pressure p_{sH} and the pressure p_{sH} acts on the face A_r. The nonreturn valve 39 shuts off, since, as described above, p_{sH} is higher than p_{sN}. When the valve 35 is in the position of rest, the chamber 15b is relieved to the tank 26. In these positions of the valves 35 and 36, the highest downwardly directed force acts on the piston 16. In the event of an increase in the control signal u_{stb}, the connection to the tank 26 is throttled. Then, an upwardly directed force determined by the magnitude of the control signal u_{stb} acts on the face A_b of the head of the piston 16, said force counteracting the downwardly acting force and consequently reducing the resultant downwardly acting force.

The functioning of a transfer press in the control device illustrated in figure 1 is described below with reference to figure 2. Figure 2 shows the position s_s of the tool part 11 (curve trace 45) and the position s_k of the tool part 12 (curve trace 46) during a work cycle of the transfer press. Since the rotational speed of the crank mechanism 13

is constant, there is a fixed relation between the crank angle φ, which is a measure of the position s_s, and the time t. It is consequently possible, instead of the respective crank angles φ_i, to consider time points t_i corresponding to these. The work cycle described below commences at the time point t_0 with a prestroke in which the tool part 11 moves from the upper reversal point OT to the lower reversal point UT. This reversal point is reached at the time point t_3. The prestroke is followed by a return stroke, in which the tool part 11 moves back from the lower reversal point UT to the upper reversal point OT. This reversal point is reached at the time point t_6. Owing to the continuous rotational movement of the crank mechanism, a new work cycle commences immediately at the time point t_6 and proceeds in the same way as the work cycle between the time points t_0 and t_6. In contrast to the movement of the tool part 11, the movement of which is permanently determined by the crank mechanism 13, the movement of the tool part 12 can be controlled by the action of hydraulic pressure medium upon the chambers 15b and 15s of the differential cylinder 15. For this purpose, a program is filed in the computing circuit 22, which, from the signals u_φ and u_{sk}, forms control signals u_{stb} and u_{sts} for the valves 35 and 36 in such a way that the position s_k of the tool part 12 corresponds to the curve trace 46. At the time point t_0, the valve 36 is in its working position, that is to say the chamber 15s is acted upon by the pressure p_{sH}. Up to

the time point t_1, the valve 35 is activated such that the tool part 12 maintains its initial position, designated by s_{k0}. In this case, in the chamber 15b, a pressure is established at which the forces acting on the piston 16 from opposite sides exactly cancel one another (taking into account the dead weight of the tool part 12 and of the workpiece 10). On account of the movement of the tool part 11, the distance between the tool parts 11 and 12 decreases in the time segment Δt_1 between t_0 and t_1. From the time point t_1 on, the computing circuit 22 activates the valve 35 in such a way that the distance between the tool parts 11 and 12 decreases further, until the tool parts 11 and 12 impinge one on the other at the time point t_2. At the time point t_2, the computing circuit 22 switches the valve 36 back into its position of rest. The energy consumption of the pump 25 is consequently reduced, since only the pressure p_{sH} of the pressure accumulator 27 is maintained, without pressure medium being extracted from the pressure accumulator 27. For the remaining part of the prestroke, that is to say in the time segment Δt_3 between the time points t_2 and t_3, and during a first part of the return stroke, for example during the time segments Δt_4 and Δt_5 between the time point t3 and t5, the valve 36 maintains its position of rest. During this time, the chambers 15b and 15s of the differential cylinder 15 are acted upon only by pressure medium from the pressure accumulator 31. In this case, the computing circuit 22 again

activates the valve 35 such that, in the chamber 15b, a pressure is established which acts on the face A_b of the piston 16 and, together with the other forces acting on the piston 16, moves the tool part 12 according to the profile of the curve trace 46. The curve trace 46 applies to a situation where the tool parts 11 and 12, together with the workpiece 10 located between them, move jointly upward as far as the time point t_4. In the time segment Δt_5, which extends as far as the time point t_5, the tool parts 11 and 12 separate from one another and release the workpiece 10 for extraction. At the time point t_5, the tool part 12 has reached its initial position s_{k0}, while the tool part 11 is still moving up to the upper reversal point OT which it reaches at the time point t_6. At the time point t_6, the computing circuit 22 switches the valves 36 again into its working position, in which the pressure p_{sH} is supplied to the chambers of the differential cylinder 15 via the lines 40 and 41. In principle, the changeover of the valve 36 into its working position may also take place at a later time point, but at the latest up to the time point t_1. The dashed line 47 shows, alternatively to the curve trace 46, the situation where the tool part 12 first moves, from the time point t_3 on, into a particular extraction position to the workpiece 10 and reaches its initial position s_{k0} again only between the time points t_5 and t_6.

Figure 3 shows only the hydraulic part of a second device, formed according to the invention, for controlling the drawing process in a transfer press. This device is identical in many parts to the device illustrated in figure 1. Components which are illustrated above a dashed and dotted line 50 in figure 1, to be precise the tool parts 11 and 12, the crank mechanism 13 and the computing circuit 22, are also not illustrated once more in figure 3 for the sake of clarity. The piston rod 17 of the differential cylinder 15, said piston rod ending at the line 50 in figure 3, leads to the tool part 12. The output signal u_{sk} from the displacement transducer 21 is fed as an input signal to the computing circuit 22. The output signal u_{φ} of the rotary-angle transducer 20 is fed as a further input signal to the computing circuit 22. From these signals, the computing circuit 22 forms the control signal u_{stb} for a hydraulic valve 51 and the control signal u_{sts} for a further hydraulic valve 52. The valves 51 and 52 are formed as proportional valves. This measure allows a sensitive control of the pressure medium flow. The valve 51, which is connected to the chamber 15b via a hydraulic line 53, controls the flow of pressure medium to the bottom-side chamber 15b. The valve 52 controls the flow of pressure medium to the rod-side chamber 15s. As in figure 1, two pumps 25 and 30, two pressure cutoff valves 28 and 32, two pressure accumulators 27 and 31 and a nonreturn valve 39 are provided in figure 3. The pressure

accumulator 31 is connected to the chamber 15s via the nonreturn valve 39 and the lines 40 and 41.

The valve 51 can be controlled continuously between two end positions by means of the control signal u_{stb}. In the end position illustrated in figure 3, the chamber 15b is relieved to the tank 26. In the other end position of the valve 51, the chamber 15b is acted upon by the pressure p_{sH}. In the case of values of the control signal u_{stb} which lie between zero and its maximum value, the valve 51 assumes an intermediate position, in which the chamber 15b is connected both to the tank 26 and to the pressure accumulator 27, the size of the respective passage cross sections being determined by the respective value of the control signal u_{stb}. The valve 52 can likewise be controlled continuously between two end positions by means of the control signal u_{sts}. In the end position illustrated in figure 3, the chamber 15s is acted upon by the pressure p_{sH}. Since the pressure p_{sH} is higher than the pressure p_{sN} in this position of the valve 52, the nonreturn valve 39 shuts off. In its other end position, the valve 52 shuts off and the chamber 15s is acted upon by the pressure p_{sN}. In the intermediate positions of the valve 52, the pressure in the chamber 15s is established at a value which lies between p_{sH} and p_{sN} and which is dependent on the magnitude of the control signal u_{sts}.

The computing device 22 activates the valves 51 and 52 such that the tool part 12 connected to the piston rod 17

follows the curve trace 46 illustrated in figure 2. The work cycle commences at the time point t_0 with a prestroke, in which the tool part 11 moves from the upper reversal point OT to the lower reversal point UT. In a time segment Δt_2 between the time points t_1 and t_2, the valves 51 and 52 are in the position of rest, illustrated in figure 3, in which the chamber 15s is acted upon by the pressure p_{sH} and the chamber 15b is relieved to the tank 26. In this valve position combination, the highest possible force acts on the piston 16. At the time point t_2 at which the tool part 11 impinges onto the tool part 12, the valve 52 closes. The chamber 15s is acted upon with pressure medium by the pressure accumulator 31 via the nonreturn valve 39 and the lines 40 and 41. The tool part 11 driven by the crank mechanism 13 displaces the tool part 11 held on the piston rod 17 actively downward. The computing circuit 22 in this case activates the valve 51 such that the desired holding counterforce of the tool part 12 is established. In this case, a reduction in the passage cross section of the connection between the chamber 15b and the tank 26 increases the holding counterforce of the tool part 12. The valve 51 to that extent acts with a controllable throttle which determines the pressure in the bottom-side chamber 15b. At the time point t_3, the tool part 12 reaches the lower reversal point u_t. The computing circuit 22 then activates the valves 51 and 52 such that both the chamber 15b and the chamber 15s are acted upon by the

pressure p_{sH}. In this case, the valves 51 and 52 are activated, in particular, such that the tool part 12 follows the curve trace 46. Here, too, in the time segment Δt_2, the differential cylinder 15 is supplied with pressure medium only from the pressure accumulator 31 charged to the lower pressure p_{sN}. This means that, in this exemplary embodiment, too, the energy consumption of the pump 25 is reduced in the time segment Δt_2, as compared with other time segments of the work cycle.

A further reduction in the energy consumption during a work cycle of the transfer press is made possible by the exemplary embodiment described with reference to figures 4 to 7. Figure 4 shows a control device in an illustration corresponding to figures 1 and 3. In so far as the same components are used in figures 1, 3 and 4, they are given the same reference symbols. For driving the tool part 12, in figure 4, there is a differential cylinder 55 which has a construction other than that of the differential cylinder 15 used in figures 1 and 3. As already in figure 3, the tool parts 11 and 12 and also the crank mechanism 13 are not illustrated once more in figure 4. The differential cylinder 55 is illustrated on an enlarged scale in figure 5. A differential cylinder of this type is known, for example, in conjunction with a commercial vehicle, from US patent specification 6,145,307. The differential cylinder 55 possesses a piston 56 which is provided with a bore 57. A

piston 58 which is fixed with respect to the housing and engages into the bore 57 forms, together with the bore 57, an inner bottom-side chamber $55b_i$. The supply of pressure medium to the chamber $55b_i$ takes place via a duct 59 in the piston 58. Furthermore, the differential cylinder 55 possesses an outer bottom-side chamber $55b_a$ and a rod-side chamber 55s. The lines 41 (coming from the valve 52) and 53 (coming from the valve 51) are connected to the chambers 55s and $55b_a$ respectively. The pressure-loaded faces of the piston 56 are designated by A_r, A_{bi} and A_{ba}. Figure 6 shows the annular face A_r of the rod-side chamber 55s. Figure 7 shows the annular face A_{ba} of the outer bottom-side chamber $55b_a$ and a circular face A_{bi} of the inner bottom-side chamber $55b_i$, the circular face A_{ba} being formed so as to be larger than the annular face A_{bi}. An electric motor 62 drives a flywheel mass 64 and a variable-displacement pump 65 via a shaft 63. The conveying volume of the variable-displacement pump 65 is adjustable between a minimum value and a maximum value by means of a control signal u_{stH}. A second shaft 66 is connected to the shaft 63 via a coupling 67. The shaft 66 drives a hydraulic machine 70, which can be controlled continuously from pump operation to motor operation as a function of a control signal u_{stM}, and the pump 30 formed as a fixed-displacement pump. The hydraulic machine 70 is connected via a hydraulic line 73 to the duct 59, leading into the chamber $55b_i$, in the piston 58 of the differential cylinder 55, said piston being

fixed with respect to the housing. Between the pressure accumulator 31 and the line 73 is arranged a nonreturn valve 75 which shuts off whenever the pressure in the line 73 is higher than p_{sN}.

From the input signals u_{φ} and u_{sk}, a computing circuit 77 forms, according to predetermined algorithms, the control signals u_{stb} and u_{sts} (in the valves 51 and 52) and further control signals u_{stH} (for the variable-displacement pump 65) and u_{stM} (for the hydraulic machine 70). For the sake of clarity, the individual electrical lines between the computing circuit 77 and the actuating members (valves 51 and 52, variable-displacement pump 65, hydraulic machine 70) are not illustrated in figure 4. The computing circuit 77 activates the actuating members such that, in this exemplary embodiment, too, the position s_k of the tool part 12 corresponds to the curve trace 46 illustrated in figure 2. The work cycle commences again at the time point t_0 with a prestroke, in which the tool part 11 moves from the upper reversal point OT to the lower reversal point UT. In the time segment Δt_2 between the time points t_1 and t_2, the valves 51 and 52 are in the position of rest, illustrated in figure 3, in which the chamber 55s is acted upon by the pressure p_{sH} and the chamber $55b_a$ is relieved to the tank 26. In this time segment, the hydraulic machine 70 is set at approximately 50% tank conveyance. In this combination, the highest possible force acts on the piston 56. At the time point t_2 at which

the tool part 11 impinges onto the tool part 12, the valve 52 closes. During the time segment Δt_3, the chamber 55s is acted upon with pressure medium by the pressure accumulator 31 via the nonreturn valves 39 and the lines 40 and 41. The tool part 12 held on the piston 56 is actively displaced downward by the crank mechanism 13 via the tool part 11 and the workpiece 10 located between the tool parts 11 and 12. In this time segment, the computing circuit 77 activates the valve 51 such that the desired holding counterforce of the tool part 12 is established. In this case, a reduction in the passage cross section of the connection between the chamber $55b_a$ and the tank 26 increases the holding counterforce of the tool part 12. The hydraulic machine 70 operates as a motor and transmits mechanical energy to the flywheel mass 64. The variable-displacement pump 65 pivots to 100% conveying volume. The pressure in the chamber $55b_a$ is regulated via the valve 51 and the hydraulic machine 70. At the time point t_3, the tool part 12 reaches the lower reversal point UT. The computing circuit 77 then activates the valves 51 and 52 such that both the chamber $55b_a$ and the chamber 55_s are acted upon by the pressure p_{sH}. Moreover, the chamber $55b_i$ is filled via the nonreturn valve 75 and the hydraulic machine 70 operated for this purpose as a pump by the computing circuit 77. The actuating members (valves 51 and 52, variable-displacement pump 65, hydraulic machine 70) are activated, in particular, such that the tool part 12

follows the curve trace 46. Here, too, in the time segment Δt_2, the differential cylinder 55 is not supplied with pressure medium from the pressure accumulator 27 charged to the higher pressure p_{sH}. This means that, in this exemplary embodiment, too, the energy consumption of the pump 25 in the time segment Δt_2 is reduced, as compared with the other time segments of the work cycle, an even better utilization of the energy employed for supplying the electric motor 62 being afforded by the use of the hydraulic machine 70.